Paleobotanical Examinations of Cretaceous and Tertiary Coals

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I.

CRETACEOUS COALS FROM GREENLAND

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PALEOBOTANICAL EXAMINATIONS OF CRETACEOUS AND TERTIARY COALS

ERNEST L. MINER

I. CRETACEOUS COALS FROM GREENLAND*

Introduction

The studies that have been made on the plant remains in coal are in no way comparable to the work that has been done on the fossil plants from other sedimentary deposits. The fine collection of Western Greenland coal, made by Mr. Carl O. Erlanson in 1928, was made available to the writer for examination. It has been dealt with in a preliminary way by Arnold (1932), and the writer has previously published descriptions of several new species from megaspores (Miner, 1932). This present paper classifies and discusses in more detail the relationship, geological age, and distribution of this coal flora.

A survey of the literature dealing with the paleobotany of coal reveals the fact that nearly all the studies made, whether microscopic or otherwise, deal more with the origin and structure of coal than with the identification and classification of the plants that contributed to the various coal beds. Those desiring a more complete and detailed discussion of the history of the microscopic examination of coal are referred to Thiessen (1913, 1920). Only those workers who have attempted to identify and classify the plant fragments seen in coal will be mentioned in this study.

Historical

Various ingenious methods for the microscopic study of coal have been employed. Witham (1833) was perhaps the first to make a microscopic investigation of coal and the first to use thin sections. He observed and illustrated cellular tissue which he considered to be of vascular plants, some of which was coniferous or phanerogamic in structure. Evidently some of the cell structures that he observed were merely cross sections of spores, as shown by the illustrations of his sections of cannel coal. Of special interest were the sections from a piece of coal that showed tissues of a plant which he thought resembled the recent Coniferae, and which he named *Pinites carbonaceus*.

Dawson (1859, 1863, 1866, 1871) studied quite extensively over a period of several years the composition of Nova Scotian coal; and while engaged in examining shale, shaly coal, and coal he observed rounded bodies for which the name *Sporangites* was proposed. He considered them "spore-cases" of *Lepidodendron, Calamites,* or similar plants. The exact nature and structure of Dawson's *Sporangities* is not clearly understood or known.

* Papers from the Department of Botany and Herbarium of the University of Michigan, No. 459.

Probably the best early descriptions and illustrations of spores, spore appendages, cuticles and various other plant fragments found in coal, ranging in age all the way from the Devonian to the Tertiary, were given by Reinsch (1884). He figured over five hundred spores referred to as *Trileteae* and interpreted them as Algae or algoid plants. The "tribe" *Trileteae* is composed of the single genus, *Triletes,* and Reinsch characterized the species by numbers rather than by specific names. He regarded the appendages of the spores as distinct parasitic organisms and described them as such. He included a variety of cuticles under *Stolidermieae.* In his interpretations he was led astray by erroneous conceptions regarding the true nature of plant fossils in coal.

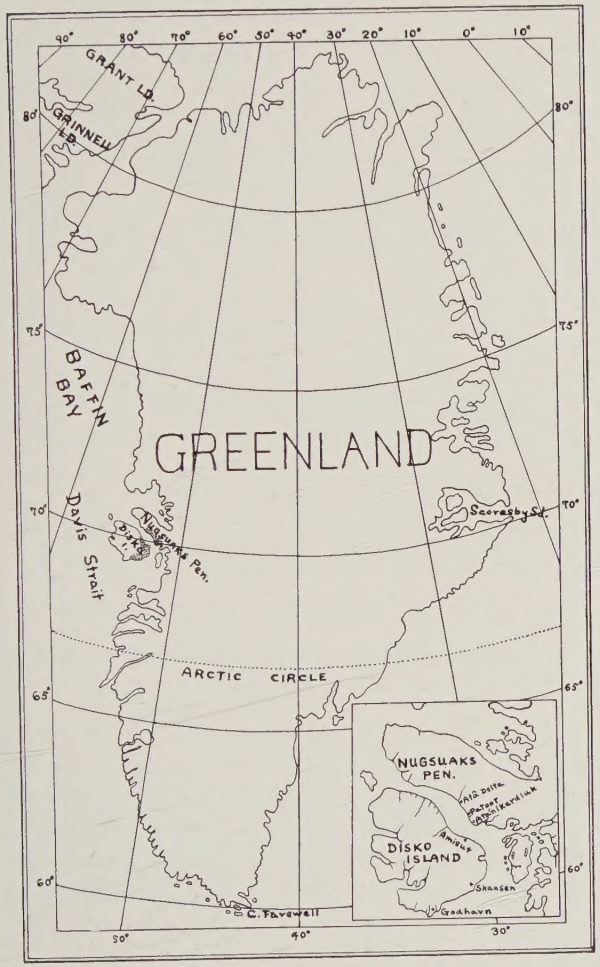
Bertrand and Renault (1892) found in Boghead coal some small plant bodies which they considered to be algae and instituted the genus *Pila* for them. Later (1893) while engaged in studying similar coals and oil shale they observed other alga-like bodies for which they formed the genus *Reinschia.*

Like most of the earlier workers, the recent investigators have also been primarily interested in the structure or origin of coal. The more recent investigations may then be grouped into two classes, those primarily concerned with the structure or origin of coal, and those with the plant remains recovered from coal; although both recognize the importance of fossils for stratigraphical purposes. In the latter group there are the excellent paleobotanical studies of Bartlett (1929), Zerndt (1930a, 1930b, 1931), Potonié (1931a, 1931b, 1931c), and Kirchheimer (1930, 1931a, 1931b). These investigators used the maceration process and were able to isolate a great variety of megaspores and microspores. The various spores were named and described, and their relationships or affinities indicated wherever it was possible to do so.

Geological Age of the Greenland Coal

All the coal examined in the present studies appears to be Upper Cretaceous, as is indicated by the paleontological and stratigraphical work of various investigators. The sedimentary rocks of Western Greenland are mainly sandstone and shale with a few layers of coal. The coal beds are lenticular and vary in thickness from a few inches to several feet (Ball, 1923, Bøggild, 1928). The series of rocks in which they occur is about 3,500 feet thick (White and Schuchert, 1898), and ranges in age, without stratigraphic break, from the Lower Cretaceous to the Eocene. From a study of the plant fossils contained in these rocks Heer (1882, 1883) recognized four floras, the Kome or Neocomian, Atane or Cenomanian, Patoot or Senonian, and Atanikerluk or Miocene. This last division is now referred to the Eocene (Bøggild, 1917, 1928). Berry (1925) states that subsequent work on this Cretaceous flora has shown that the boundaries of Heer's units were largely arbitrary, although the main bodies of his floras are quite distinct.

The Kome series is best developed on the north side of the Nugsuaks Peninsula. The flora of this series as a whole is considered similar to that of the Potomac formation by White and Schuchert (1898). No coal from the Kome series was included in the present study.



Map 1. Map of Greenland showing the position of the region studied. This region is indicated by the shaded area. The insert is a more detailed map of this region, giving the principal localities where coal was collected. Modified from Danish government maps, Copenhagen. (Bøggild 1928; K. J. V. Steenstrup 1888).

The Atane series has the widest distribution, occurring over almost the entire area, on the north side of Disko Island, the north and south sides of the Nugsuaks Peninsula and Upernivik Island. From paleobotanical evidence White and Schuchert (1898) state that this series is closely correlated with the Amboy calys, but the faunal evidence indicate that it is to be correlates with the Fox Hills sandstone or the Pierre shale of the Montana group.

The Patoot series is higher than the Atane and lithologically and stratigraphically inseparable from it. At the locality called Patoot this series commences at about 500 feet above sea level and extends upwards over 2,000 feet, where it passes into the Tertiary (White and Schuchert 1898). From a study of the invertebrate fauna contained in this series Loriol (1893) classified it as Senonian in age and this conclusion is supported by the later works of Ravn (1918). Berry (1925) shows that the flora has many features in common with the Dakota, Raritan, Magothy, Ripley and Atane floras. Seward (1925, 1927), after making a critical study and revision of the Cretaceous floras of Western Greenland, concludes that a more thorough study of the section is necessary, because with the available facts it is difficult to correlate them accurately with other regions. He also expresses the opinion that these floras represent more fully than any others the early stages in the transitional period from an older Jurassic-Wealden vegetation to the type that continued into the Tertiary.

On Disko Island the Cretaceous-Tertiary boundary has not been determined. However, at Skansen, Seward (1927) examined Cretaceous strata at an elevation of 1,900 feet. The highest collection made on this island by Erlanson was at approximately 1,380 feet, and the highest made on the Nugsuaks Peninsula was at Patoot at a height of about 1,248 feet. It is apparent, therefore, that all the collections were made at levels well within the boundaries of the Upper Cretaceous as given by Seward (1927), and White and Schuchert (1898).

Methods

In this study the maceration method alone was used as it is the most satisfactory one for the study of the isolated and fragmentary plant remains, such as spore exines, seeds, cuticles, charcoal, etc., recovered from coal.

Schulze (1855) was the first to adapt to lignite and bituminous coal the maceration process used in the separation and isolation of anatomical elements in living plants. His method has since been variously modified by different workers. The principles for the procedure followed here were those given by Bartlett (1929).

The coal was macerated and prepared for microscopic examination by soaking it first in dilute nitric acid (5-10%) for a period of several months to a year, depending on the kind of coal. Then it was washed in water to remove the acid, and placed in a dilute sodium hydroxide solution (2%) for a few days or until the maceration was complete. The resulting brown liquid was washed out with water, leaving a residue of (a) mineral inclusions, such as sand, (b) organic remains such as spore exines, seeds, cuticles, charcoal,

resin, etc. This residue was examined under a binocular microscope and the various fragments removed. These plant fossils, with the exception of large pieces of charcoal and large seeds, were mounted in euparal (Miner, 1932).

The charcoal was embedded in paraffin by the butyl alcohol process and cut on a rotary microtome in serial sections 15-25μ in thickness. Transverse, radial, and tangential sections were cut from each specimen. The charcoal sections were mounted on slides without removing the paraffin as the material would disintegrate if the paraffin was removed. This necessitated the use of a mounting medium which did not contain a solvent of paraffin. Euparal was satisfactory. To leave the embedding matrix in the material, as is sometimes done with material embedded in celloidin, did not appear to affect the transparency of the sections. Some samples did not yield any pieces of charcoal large enough to be sectioned, so the small fragments were teased apart and then mounted.

"Smear" mounts were made of the finer plant debris in which particles were too small to be examined with a binocular microscope. The material for the "smear" mounts was collected at the time the sodium hydroxide was washed from the samples, as the water from the washing process was charged with fine plant remains. After the material had been allowed to settle, the excess water was decanted and the residue mixed with a suitable mounting medium, such as brown glucose ("karo") syrup or glycerin jelly. The syrup mixture was then gently heated until it became of proper consistency for mounting. For this method of recovering minute plant tissue from macerated coal the writer is indebted to Professor H. H. Bartlett.

Policy with Regard to Naming Fossils of Undetermined Affinity

A successful treatment of such isolated plant fragments as occur in coal necessitates the use of names for spore exines, cuticles, seeds, etc., regardless of whether or not their affinities and relationships are known. Thiessen (1920) is opposed to giving definite names to such fossils without knowing their affinities, but yet he shows quite convincingly that they are stratigraphically significant and that correlations may be established through comparison of the characteristic fossils. Zerndt (1930a, 1930b, 1931) gives definite names to isolated spores, because he also finds that it is possible to differentiate the various strata with the aid of such spores. He places the megaspores in the form-genus *Triletes*. Potonié (1931a, 1931b, 1931c) in his studies on lignite, uses for the various small spores and pollen grains, such generic names as *Sporonites, Pollenites,* and also such compounds as *Piceae-pollenites, Tiliae-pollenites, Gossippii-pollenites,* and *Polypodii-sporonites*. The form-genera *Sporonites* and *Pollenites* are for small spores and pollen grains of unknown affinity, and the other generic designations are for pollen grains or small spores the affinities of which are known and are indicated by the generic name.

It seems, that if a fossil is distinctive enough to be used in determining correlations it should have a specific name. If such a fossil is not named it can not be included in indexes, nor can it be conveniently referred to in the literature, so as a result the original record of it is soon lost to science. In

this connection it must be remembered that although biological science does not consist entirely of names, yet progress is difficult without them.

Enumeration of the Plants

Bryophyta

Chrysotheca gen. nov.

Plant body small, smooth, ovate, oblong-ovate, or lanceolate, with few to several plications, sessile or apparently short stalked; mouth fringed or slightly laciniate.

Chrysotheca diskoensis sp. nov.

Plant body smooth, ovate, oblong-ovate, or lanceolate, 232-348 x 680-1029μ, generally 280 x 796μ, 3-6 plicate to the base, sessile or apparently short stalked; mouth slightly fringed. Amisut, east coast of Disko Island, Greenland; Upper Cretaceous. Plate 18, Figures 1-10. Walton (1925, 1928) instituted the form-genus *Hepaticites* for fossil plants that give evidence of a relation to living *Hepaticae* and of the characteristics which distinguish them from the other divisions of the plant kingdom. The genus is based upon the vegetative remains of some Carboniferous liverworts, resembling the thalli of the anacrogenous *Jungermanniales*. He also shows that of the many fossil organisms described under generic names suggesting affinities to the *Hepaticae*, only a very few afford any reliable information concerning this group. The genus *Chrysotheca* is based upon plant remains which resemble the perianths of many of the *Jungermanniales*. The specimens are rather delicate sack-like structures varying in shape from ovate to lanceolate, with 3 to 6 plications or longitudinal furrows extending from the base to the apex and converging at the mouth or apical opening. The mouth is apparently fringed or slightly laciniate. Cotypes. Slides No. 15455, 15456, Museum of Paleontology, University of Michigan.

Lycopodiales

The following species, *Selaginellites Erlansonii, S. papillosus, S. greenlandicus, S. echinatus, S. borealis, S. inornatus, S. subrotundus, S. Ariadnae,* and *S. Arnoldii,* were recovered from this coal and previously discussed (Miner, 1932). Further examination of the coal has not given any new locality records, except for *S. Arnoldii.* This species besides occurring in the coal from Skansen, east coast of Disko Island, two miles inland at an altitude of 140 meters, and at Patoot, southeast coast of Nugsuaks Peninsula, at an elevation of 165 meters, has also been found in the coal from the latter locality but at a height of only 85 meters. A specimen is illustrated on Plate 18, Figure 22. Slide No. 15466, Museum of Paleontology, University of Michigan.

Filicales

Thecopteris gen. nov.

Small, or medium-sized fern sporangia, annulus vertical and incomplete,

sometimes indistinct; spore masses compact, circular or nearly so; spores small, deltoid, numerous.

Thecopteris major sp. nov.

Sporangia 415 x 498μ in diameter; annulus apparently vertical and incomplete, sometimes indistinct, exact position of the stomium uncertain; spore masses orbicular or nearly so, slightly smaller than the sporangia; spores deltoid 25-35μ in diameter, numerous. Skansen, east coast of Disko Island, Greenland; two miles inland at altitude of 385 meters; Upper Cretaceous. Plate 18, Figures 11-15. Cotypes. Slides No. 15460-15463, Museum of Paleontology, University of Michigan.

Thecopteris minor sp. nov.

Sporangia 315-398μ in diameter; annulus indistinct, position of stomium uncertain; spore masses slightly smaller than sporangia, usually more or less orbicular; spores deltoid, 35-45μ in diameter, numerous. Skansen, east coast of Disko Island, Greenland; two miles inland at an altitude of 385 meters, and one mile inland, at an elevation of 175 meters; Upper Cretaceous. Plate 18, Figures 16-19. In this species and the preceding one the spore masses, without the sporangia, were much more abundant than those with the sporangia. The sporangium and its annulus apparently disintegrate quite rapidly. The exact relationship of this fern are rather difficult to determine from the information available. If the annulus can be interpreted as being equatorial, then these resemble the *Gleicheniaceae*, but if the annulus is vertical and incomplete as it apparently appears to be then they show a closer affinity to the *Polypodiaceae*. Cotypes. Slides No. 15460, 15462, 15464, Museum of Paleontology, University of Michigan.

CONIFERALES

Cedroxylon sp.

Transverse.—Tracheids square to hexagonal, rather large but variable in size. Growth rings distinct. Rays narrow. No resin canals or wood parenchyma visible.

Radial.—Bordered pits uniseriate, separate or contiguous; circular or slightly flattened when contiguous. Ray cells with one or two simple, circular or elliptical pits per tracheid. No ray tracheids, or resin canals determinable. Bars of Sanio absent.

Tangential.—Rays narrow, apparently uniseriate and 4-15 cells high. Skansen, east coast of Disko Island, Greenland; two miles inland at an altitude of 140 meters; Upper Cretaceous. Plate 20, Figures 67-69; Text Figure 1. Slide No. 15502, Museum of Paleontology, University of Michigan.

The form-genus *Cedroxylon* is used here as defined by Bailey (1933) in his recent investigations on the range of structural variability in certain recent and Mesozoic coniferous woods. No vertical resin canal could be detected in the transverse section which has approximately an area equal to about one

fourth of a square inch. The bordered pits occur on the radial walls of the tracheids and are of the type shown in Text Figure 1. The separately spaced pits (Text Figure 1, a, d, e, Plate 20, Figure 69) were the most common ones observed. The contiguous bordered pits (Text Figure 1, b, c.) with the sides slightly flattened at point of contact were observed quite frequently. The tracheid pitting thus shows abietinous and araucarian characteristics, with the former predominating. At no time were any structures seen that could be interpreted as bars of Sanio. The apparent absence of them might be attributed to the charred condition of the wood, but this hardly seems possible as I have observed them in charcoal from Montana coal. The ray tracheids and horizontal resin canals, if present, may have been obscured during fossilization.

Cedroxylon spp.

One of two specimens from Skansen, two miles inland at an altitude of 385 meters, showed three growth rings (Plate 20, Figure 70) and tracheids with bordered pits arranged as shown in Text Figure 2; the other had two growth rings and tracheid pitting as illustrated in Text Figure 3. No doubt both specimens belong to the same species as their pitting is only slightly varied. The bordered pits are oval in shape, separate and arranged in one or two vertical rows; those in two vertical rows vary from opposite to alternate. No bars of Sanio are present. The wood rays are apparently uniseriate and probably 2-8 cells high. Slides No. 15503, 15504, Museum of Paleontology, University of Michigan.

A specimen from Skansen, one and one-half miles west and one and one-half miles inland, at an altitude of 70 meters showed a growth ring similar to those in Plate 20, Figure 70. The bordered pits are circular and the same arrangement as those figured in Text Figure 1, a, and b. Slide No. 15505, Museum of Paleontology, University of Michigan.

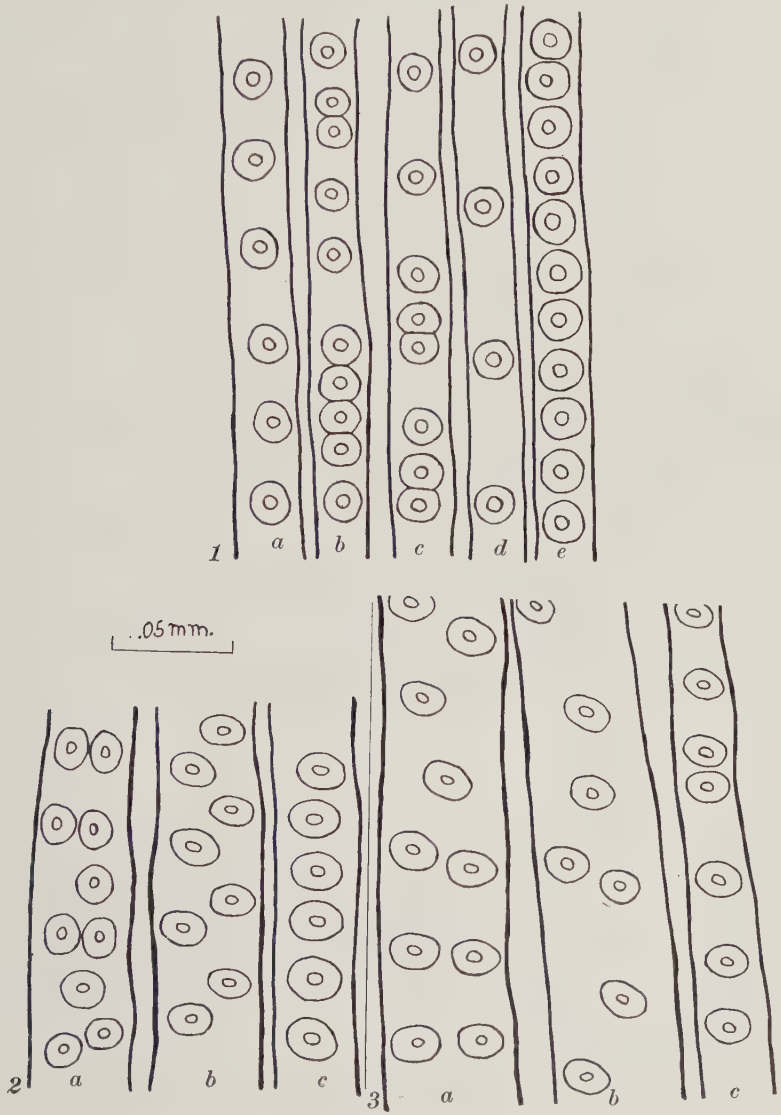
Circular and separate bordered pits, as well as a few contiguous ones such as those illustrated in Text Figure 1, were observed in a small piece of charcoal found in the coal sample collected at Evinasugsuit. Slide No. 15506, Museum of Paleontology, University of Michigan.

In the coal from Amisut, some specimens of charcoal showed uniseriate, oval bordered pits (Text Figures 1, c, and 2, c.), whereas the pitting in other specimens was circular and separate or contiguous (Text Figure 1). Slides No. 15507, 15508, Museum of Paleontology, University of Michigan.

The carbonized wood from Skansen, one-quarter of a mile west in a stream bed, at an altitude of about 15 meters, showed bordered pits that were slightly more oval than those illustrated in Text Figures 2, c, and 3, c. Circular bordered pits similar to those in Text Figure 1, a, b, e, were also observed in this material. No bars of Sanio were observed on any of the tracheids. Slide No. 15509, Museum of Paleontology, University of Michigan.

Both the abietineous and araucarian types of tracheary pitting occur in

Mesozoic conifers. In the former the bordered pits are more or less widely placed and when in more than one vertical row they are opposite each other, but in the latter type the bordered pits are contiguous and flattened and, when in more than one vertical series, alternate.



Figs. 1-3. *Cedroxylon* spp. These drawings illustrate the arrangement of the bordered pits that occur on the tracheids of the various specimens of charcoal.

The presence or absence of the so-called "rims" or "bars" of Sanio has been regarded by some paleobotanists as the most reliable diagnostic character in distinguishing woods of abietineous and araucarian affinities. The absence of these structures has been taken to indicate araucarian affinity, but Bailey (1933) has shown that they should not be relied upon entirely in the identification of fossil woods.

Fragments of carbonized wood or actual charcoal, the so-called mother of coal, occurred in almost every sample of coal examined. Nearly all the specimens observed, appeared to have been charred before burial in the original peat deposits. Such portions of the coals as had obviously been derived from woody material, always dissolved out completely during the process of maceration. The charcoal, on the contrary, was insoluble and always retained its structure. It seems certain therefore that the carbonized wood was charred by forest fires contemporary with the deposition of the beds, and that it was originally deposited as charcoal and not as wood.

Angiospermae

Phyllodermium gen. nov.

Isolated cuticles or epidermal fragments, epidermal cells variously shaped; subsidiary cells specialized or sometimes not differentiated from adjacent epidermal cells; stomata scattered, not definitely oriented.

Phyllodermium Reinschii sp. nov.

Stomata irregularly scattered with no definite orientation; guard cells allantoid, 12-14μ wide, 35-50μ long; guard cells thickened in an elliptical rim around the stomatal opening; lateral and polar subsidiary cells not specialized in shape or size, slightly smaller than surrounding epidermal cells; epidermal cells polygonal, cell walls straight and smooth. Amisut, east coast of Disko Island, Greenland; Upper Cretaceous. Plate 21, Figures 72 and 73; Text Figure 5. Cotype. Slide No. 15486, Museum of Paleontology, University of Michigan.

Phyllodermium nervosum sp. nov.

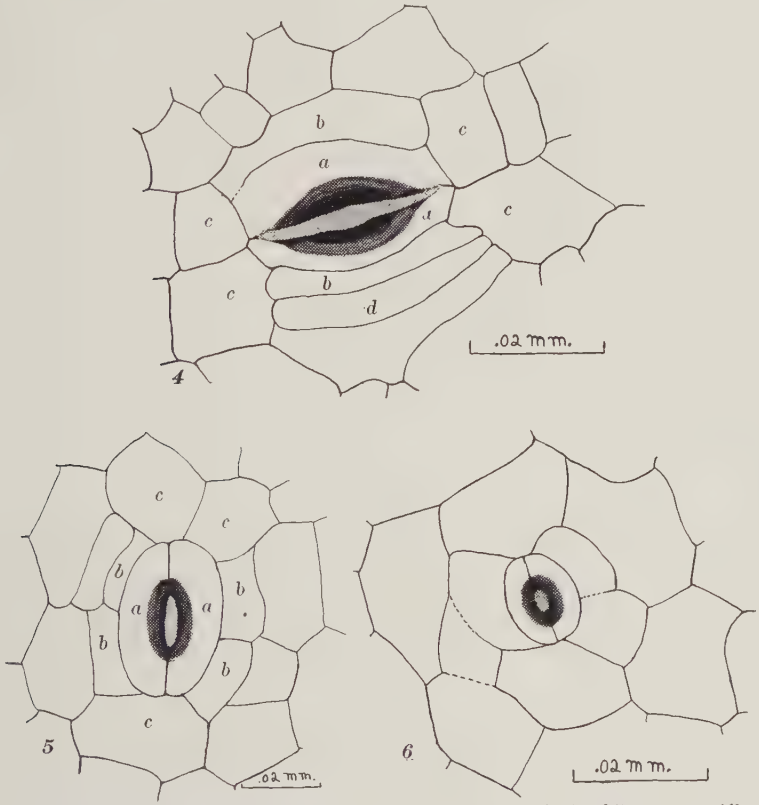
Stomata scattered with no definite orientation; guard cells 7-10μ wide, 15-33μ long; thickenings of guard cells somewhat lunate or seen in spindle-shaped pairs; lateral subsidiary cells narrow, oblong, as long as or longer than guard cells, one of two similar encircling cells present; polar subsidiary cells apparently not differentiated from surrounding epidermal cells; epidermal cells variously shaped, but mostly rectangular to square; cell walls straight and smooth. Skansen, east coast of Disko Island, Greenland; two miles inland at an altitude of 140 meters; Upper Cretaceous. Plate 21, Figures 74 and 75; Text Figure 4. Holotype. Slide No. 15482, Museum of Paleontology, University of Michigan.

Phyllodermium perplexum sp. nov.

Stomata scattered with no definite orientation; guard cells allantoid, 3.5-

7μ wide, 7-15μ long; guard cell thickenings nearly semicircular; lateral and polar subsidiary cells smaller than adjacent epidermal cells, otherwise not differentiated; epidermal cells polygonal to square, cell walls straight and smooth. Skansen, east coast of Disko Island, Greenland; two miles inland at an altitude of 140 meters; Upper Cretaceous. Plate 20, Figure 62; Plate 21, Figures 76 and 77; Text Figure 6. Cotype. Slide No. 15483, Museum of Paleontology, University of Michigan.

In the literature the terminology applied to the cells surrounding the stomata varies considerably. The specialized epidermal cells next to the guard cells are variously called accessory, auxiliary, subsidiary, supporting, or girdling cells. Florin (1931) recently revised the terminology applied to these cells and called the cells bordering the guard cells, subsidiary cells; and any specialized cells around the subsidiary cells encircling cells. In Text Figures 4 and 5 the arrangement of these cells is shown and the terms applied to them are given.



Figs. 4-6. (4) *Phyllodermium nervosum* sp. nov. (5) *P. Reinschii* sp. nov. (6) *P. perplexum* sp. nov. In (4) and (5) the cells adjoining the stomata are indicated; a, guard cells; b, lateral subsidiary cells; c, polar subsidiary cells; d, encircling cell.

The importance of epidermal characters as indicators of phylogenetic relationship has been discussed in considerable detail by Thomas (1930), Bandulska (1930-31, 1931), Florin (1931), Harris (1926, 1932), and others. With the exception of Bandulska, they were dealing almost entirely with gymnosperms. They find that in both recent and fossil plants cuticle characters are of diagnostic value. The work of Odell (1932) shows that any character of the epidermis of the vegetative organs of living angiosperms is unsatisfactory for diagnostic work. The epidermal characters of living angiosperms do not insure accurate specific or generic diagnosis, and this no doubt holds true also for fossil angiosperms.

Types of Cuticles

Epidermal or cuticular remains were found in almost every sample examined, but were much more abundant in some samples than in others. Cuticles without stomata or other characteristic features were more numerous and common than those with such characters. The most common cuticles without stomata and other similar tissues met with in this study will be designated as unnamed types, because of the lack of definite diagnostic features.

Type A.—This cuticle has the stomata arranged in rows, but the guard cells have disappeared leaving only a cavity. The other epidermal cells are long and narrow. The stomata do not appear to be definitely orientated, but otherwise this specimen is similar to the type of cuticle found in some of the Coniferae. Plate 20, Figure 62. Slide No. 15487, Museum of Paleontology, University of Michigan.

Type B.—The cells of this cuticle are mostly rectangular or square. The cell walls are very sinuous, and are of the type very common to many of the gymnosperms. Plate 22, Figure 78. Slide No. 15483, Museum of Paleontology, University of Michigan.

Type C.—The cells are rectangular or square but larger than those of Type B. The cell walls are sinuous but less so than in the preceding specimen. Cells of this type are also found in many gymnosperms. Plate 22, Figure 79. Slide No. 15483, Museum of Paleontology, University of Michigan.

Type D.—This is a rather thin cuticle with narrow hexagonal or somewhat rectangular cells. Plate 22, Figure 80. Slide No. 15492, Museum of Paleontology, University of Michigan.

Type E.—A rather thin cuticle with short, broad, rectangular or square cells. Plate 22, Figure 81. Slide No. 15849, Museum of Paleontology, University of Michigan.

Type F.—A thin cuticle with hexagonal cells. This type and types D and E were perhaps the most frequently observed cuticles. Plate 22, Figure 82. Slide No. 15488, Museum of Paleontology, University of Michigan.

Type G.—A thick cuticle with polygonal cells. This type is similar to type F in cell size and shape, but differs mostly in the greater thickness of

the cell walls. Plate 22, Figure 83. Slide No. 15491, Museum of Paleontology, University of Michigan.

Type H.—A thick specimen with small rectangular or square cells arranged more or less in definite rows. This appears to be more like cork tissue than epidermis. Plate 22, Figure 84. Slide No. 15490, Museum of Paleontology, University of Michigan.

The distribution of the types of epidermal or similar tissues is given in Table I.

Harris (1926, 1931) found that oxidative maceration followed by an alkali destroys the cuticles of ferns but not those of gymnosperms or of angiosperms. Since that type of maceration was used to soften the coal, perhaps most of the cuticles figured belong to the latter groups.

Plantae Incertae Sedis

Spermatites gen. nov.

Small, hollow structures varying considerably in size and shape, oblong-elliptical, ovate, oval, obovate, orbicular, or phaseoloid; wall cells small, square, hexagonal or rectangular; orifice small, apical or slightly lateral; base a dense mass of compact cells, sessile or short stalked. Plate 18, Figures 26-28; Plate 19, Figures 29-55; Plate 20, Figures 56-60. These very interesting little fossils rank next to *Selaginellites* (Miner, 1932), as the predominating type recovered from this coal. As to the exact affinities of these forms nothing definite can be said. Arnold (1932) wrote of them as "structures simulating bryophytic antheridia," but there is nothing exactly comparable to them among the present day Bryophyta. Superficially they somewhat resemble the perianth of *Sphaerocarpus*, but upon a closer examination, these organs appear quite different in structure. The possibility of their being sporangia was considered, but if so, one would expect to find at least a few spores associated with them, but spores were not found. Perhaps these fossils represent primitive orthotropous or slightly amphitropous seeds in which the orifice represents the micropylar opening and the dense basal portion the chalaza. The generic name *Spermatites* is employed as a convenient designation for such unassigned organs. Characteristic differences in size and shape must suffice to distinguish between species.

Spermatites elongatus sp. nov.

Oblong, or oblong-elliptical, apex obtuse; 298-448μ wide, 730-1080μ long, average 354 x 955μ; wall cells square to rectangular, 15-30μ wide, 30-75μ long; orifice apical. Skansen, east coast of Disko Island, Greenland; two miles inland at altitude of 140 meters; Upper Cretaceous. Plate 19, Figures 30-36, 38. Skansen, east coast of Disko Island, Greenland; two miles inland at an altitude of 385 meters; Upper Cretaceous. Plate 19, Figures 29, 37. This species is distinguished by its parallel or nearly parallel sides, and in being several times longer than wide. It is nearly uniform in width throughout the greater part of its length. The apex is obtuse and the pore is ter-

minal. The character of the small cells around the pore was rather difficult to determine. This species was perhaps the most abundant of this type of fossil. Cotypes. Slides No. 15468, 15469, 15471, 15474, 15475, 15479, 15480, 15481, Museum of Paleontology, University of Michigan.

Spermatites orbicularis sp. nov.

Orbicular or nearly so, 698-714μ wide, 730-865μ long, average size being about 720 x 780μ; wall cells square, rectangular, or hexagonal, mostly hexagonal, 26-45μ wide, 37-60μ long; orifice apical. Patoot, southeast coast of Nugsuaks Peninsula, Greenland, at 165 meters; Upper Cretaceous. Plate 18, Figures 27, 28. Skansen, east coast of Disko Island, Greenland; 2 miles inland at altitude of 140 meters. Plate 18, Figure 26. This uncommon type is characterized by its circular or nearly circular shape. The wall is mostly composed of hexagonal cells. The pore is terminal but the structure of the surrounding cells could not be determined. Cotypes. Slides No. 15477, 15480, Museum of Paleontology, University of Michigan.

Spermatites arcuatus sp. nov.

Phaseoloid, 415-481μ wide, 697-863μ long, average size about 442 X 780μ; wall cells square, or rectangular, mostly rectangular, 20-40μ wide, 30-67μ long; orifice apical. Skansen, east coast of Disko Island, Greenland; 2 miles inland at an altitude of 140 meters; Upper Cretaceous. Plate 19, Figures 48-51. The distinguishing feature of this species is its shape, with one side rounded or convex and the other side nearly straight or concave. It is rarely over twice as long as broad, with its greatest breadth at the middle. Both ends are somewhat obtuse, and the pore is apical. This species was not as common as *S. elongatus* but more so than *S. orbicularis*. Cotypes. Slides No. 15468, 15472, 15475, Museum of Paleontology, University of Michigan.

Spermatites ovatus sp. nov.

Ovate, 365-432μ wide, 780-946μ long, average about 386-847μ; wall cells rectangular, 22-37μ wide, 37-60μ long; orifice apical. Skansen, east coast of Disko Island, Greenland; 2 miles inland at an altitude of 149 meters; Upper Cretaceous. Plate 19, Figures 39, 40. This type is broadest just above the dense basal portion, and the sides taper gradually to an acuminate apex. The pore is terminal. This species was also rather uncommon, occurring about as frequently as *S. arcuatus*. Cotypes. Slides No. 15472, 15480, Museum of Paleontology, University of Michigan.

Spermatites nanus sp. nov.

Narrow elliptical, 266-315μ wide, 598-680μ long, average near 290 x 647μ; wall cells rectangular, 18-26μ wide, 30-45μ long; orifice apical. Skansen, east coast of Disko Island, Greenland; 2 miles inland at an altitude of 140 meters; Upper Cretaceous. Plate 19, Figures 52, 54. Skansen, east coast of Disko Island, Greenland; 2 miles inland at altitude of 385 meters; Upper Cretaceous. Plate 19, Figure 53. Although usually over twice as long as

wide, it is easily distinguished from *S. elongatus* by its small size. The sides are slightly rounded and the greatest width is through the central portion. The pore is terminal just as in most of the other species. This species has proved to be rather uncommon. Cotypes. Slides No. 15479, 15481, Museum of Paleontology, University of Michigan.

Spermatites ellipticus sp. nov.

Obovate-elliptical, 382-580μ wide, 664-930μ long, average about 465 x 780μ, apex more or less rounded; wall cells rectangular, 26-37μ wide, 35-52μ long; orifice apical. Skansen, east coast of Disko Island, Greenland; 2 miles inland at altitudes of 140 meters and 385 meters; Upper Cretaceous. Plate 19, Figures 41, 43-47. Patoot, southeast coast of the Nugsuaks Peninsula, Greenland, at an altitude of 165 meters; Upper Cretaceous. Plate 19, Figure 42. This rather common species is characterized by being not over twice as long as wide, with usually rounded sides and apex, and its greatest width being at or slightly above the middle. This species is found as abundantly as *S. elongatus*. Cotypes. Slides No. 15470, 15473, 15476, 15477, 15478, 15480, Museum of Paleontology, University of Michigan.

Spermatites pylophorus sp. nov.

Obovate, oblong-elliptical, 315-531μ wide, 764-1029μ long, average being about 420 x 860μ; wall cells square to rectangular, 20-30μ wide, 26-52μ long; orifice lateral, near the apex. Skansen, east coast of Disko Island, Greenland; 2 miles inland at an altitude of 140 meters; Upper Cretaceous. Plate 19, Figure 55; Plate 20, Figures 56-60. This species varies a little more in size and shape than do the others in this form-genus. Its distinguishing feature is the lateral position of the orifice. The position of the orifice appears to be natural and not the result of any distortion. This type was about as abundant as *S. ellipticus*. Cotypes. Slides No. 15467, 15475, 15478, 15479, 15480, Museum of Paleontology, University of Michigan.

Carpolithus Linn.

Carpolithus patootensis sp. nov.

A small seed, ovate, plano-convex; 4 mm. wide, 6 mm. long, and 1 mm. thick; testa smooth; point of attachment apparently near the base on the plane side. Patoot, southeast coast of the Nugsuaks Peninsula, at an altitude of 165 meters; Upper Cretaceous. Plate 18, Figures 23-25. Only a single specimen of this small seed was found. It is rounded on the one side and more or less flattened on the other; widest at the middle and not much longer than wide. Holotype. No. 15459, Museum of Paleontology, University of Michigan.

Carpolithus amisutensis sp. nov.

A minute seed, ovate-elliptical, 1.4 mm. wide, 3 mm. long, about .5 mm. thick; testa rugose; no point of attachment discernible. Amisut, east coast of Disko Island, Greenland, at an altitude of 1 meter; Upper Cretaceous. Plate 18, Figure 21. Only a single specimen of this seed was found. It is just a little over twice as long as wide, with the greatest width near the mid-

dle. The sides are slightly rounded and wavy in outline, due to the wrinkled nature of the seed coat. In the type specimen part of the seed coat has been broken away. Holotype. No. 15458, Museum of Paleontology, University of Michigan.

Alatampulla gen. nov.

Small winged seeds, longer than broad; wing rather uniform in width, completely surrounding the nucula or nucular cavity. This genus differs from *Samaropsis* in that in the latter genus are included seeds of the samaroid type which are approximately circular, and much larger.

Alatampulla Bartlettii sp. nov.

Winged seeds, elliptical, .6-1.1 mm. wide, 1.3-2.3 mm. long; wing .1 mm. in width, slightly narrower at the apex and wider at the base; nucular cavity vase-shaped, .4-.6 mm. wide, 1-1.6 mm. long; surface smooth. Amisut, east coast of Disko Island, Greenland; Upper Cretaceous. Plate 18, Figure 20, Skansen, east coast of Disko Island, Greenland; 2 miles inland at an altitude of 140 meters. Three specimens of this very interesting little winged seed were found. Cotype. Slide No. 15457, Museum of Paleontology, University of Michigan.

Fossilis Incertae Sedis

Arcellites gen. nov.

Body small, circular with few to several short tube-like appendages, surface pitted, pits minute.

Arcellites disciformis sp. nov.

Rotund, 265-350μ in diameter, the average being 310μ; surface pitted; 12-24 tube-like appendages, 24-30μ in width and 35-88μ in length, with sides usually parallel, or sometimes slightly constricted near the base; orifices of appendages broadly elliptical, averaging about 10 X 14μ in diameter. Skansen, east coast of Disko Island, Greenland; 2 miles inland at an altitude of 140 meters; Upper Cretaceous. Plate 20, Figures 61, 64-66. This fossil resembles somewhat a flattened exine of a megaspore, but the arrangement and structure of the tube-like appendages seems to indicate that it is the chitinous shell or covering of some small unicellular animal rather than the remains of a plant. Some of the fresh water *Rhizopoda* have similar chitinous shells, such as those in the genus *Arcella*. While the species described above differs greatly in many important respects from present day fresh water *Rhizopoda,* it is not at all improbable that it could not be an extinct form of that group or of a closely related one. The tube-like appendages are unknown in any of the living rhizopods, and no other special opening for a mouth could be detected in this species. The openings into the specimens appear to be through the appendages. The conditions necessary for the accumulation of peat are usually characteristic of the habitats of many of the fresh water rhizopods. Cotypes. Slides No. 15497, 15498, Museum of Paleontology, University of Michigan.

Table 1. Distribution of the fossils recovered from the Greenland Coal.

Species / Localities	Amisut (No other data)	Amisut At altitude of 1 meter.	Atanikerdluk At end of peninsula at sea level.	Evinasugsuit along coast between Skansen and Godhavn.	Patoot At altitude of 85 meters.	Patoot At altitude of 165 meters.	Patoot At altitude between 200 and 300 meters.	Skansen 2 miles inland at altitude of 140 meters.	Skansen 2 miles inland at altitude of 385 meters.	Skansen 1 mile inland at altitude of 175 meters.	Skansen 1 quarter mile west in stream bed at 15 meters.	Skansen 1 and one-half miles west and 1 and one-half inland at altitude of 70 meters.
Selaginellites Arnoldii					+	+		+				
S. borealis						+		+				
S. Ariadnae								+				
S. inornatus								+				
S. echinatus								+				
S. greenlandicus								+				
S. Erlansonii								+				
S. papillosus								+				
S. subrotundus								+				
Chrysotheca diskoensis	+								+			
Thecopteris major									+	+		
T. minor									+			
Spermatites elongatus								+	+			
S. orbicularis						+		+				
S. arcuatus								+				
S. ovatus								+				
S. nanus								+	+			
S. ellipticus						+		+	+			
S. pylophorus								+				
Carpolithus patootensis						+						
C. amisutensis		+										
Alatampulla Bartlettii	+							+				
Phyllodermium Reinschii	+											
P. nervosum								+				
P. perplexum								+				
Arcellites disciformis								+				
Cuticles												
Type A.								+				
Type B.								+				
Type C.								+				
Type D.			+			+	+	+	+			
Type E.	+	+				+	+	+				
Type F.	+					+				+		
Type G.	+							+				
Type H.		+				+			+			
Bordered pits												
Type of Text Figure 1, a.	+			+				+			+	+
Type of Text Figure 1, b.								+				+
Type of Text Figure 1, c.	+			+				+				
Type of Text Figure 1, d.	+							+			+	
Type of Text Figure 1, e.				+				+			+	
Type of Text Figure 2, a.									+			
Type of Text Figure 2, b.									+			
Type of Text Figure 2, c.	+								+		+	
Type of Text Figure 3, a.									+			
Type of Text Figure 3, b.									+			
Type of Text Figure 3, c.									+		+	

Climate

The question as to the nature of the climate during any geological interval is always interesting and offers opportunity for speculative thought. This is especially true when fossil forms are found in the Arctic regions, the only living representatives of which are at the present time restricted to the equatorial zone.

The presence of apparently tropical species in the rocks as far north as Greenland has led to the belief that a tropical or subtropical climate once existed in that northern country. To account for this various explanations and theories have been advanced, such as the wandering of the poles or the sliding movement of the earth's crust, all of which would seem to have been unnecessary if the fossil flora had been considered or known in its entirety. There is of course no doubt that the climate in Western Greenland was warmer during the Cretaceous time than at present, just as the climate of the Great Lakes and adjacent regions is warmer today than during the Pleistocene glaciation. Since environments in the world have changed during the course of time, the plants themselves have all probably changed in their reactions to external conditions.

Seward (1927) and Berry (1930) have recently questioned the existence of a tropical climate in this northern country during the late Mesozoic. They think that the flora thrived there under much more temperate conditions than has been assumed before. This assumption is supported from the present study of the Cretaceous coals of Western Greenland.

There can be little doubt that the plants which contributed to these coal beds did grow within the Arctic region, and that the coal is autochthonous in origin. There has never been any substantial evidence that coal is of allochthonous origin. Coal is metamorphosed peat and one of the conditions necessary for the favorable formation of peat is a cool to moderate climate. Peat forms in Arctic regions at the present time just as it did in past geological ages. It is much more extensive in Arctic regions than in the tropics as conditions in the latter are unfavorable for the accumulation of large or good peat deposits.

Growth rings occur in woods which grow in regions where there are periods of suspension in the activity of growth. This interruption of growth may be due to drought or to the lowering of the temperature. In general, then, growth rings indicate seasonal changes in a climate. Antevs (1925) states that growth rings are most marked in temperate zones and the distinctness increases with the latitude until climatic conditions exert a checking influence on their development. In Arctic regions growth rings are often indistinct and sometimes difficult to discern, while in the tropics they vary from distinct ones to those that are indiscernible or lacking. The lack of growth rings is an exception in temperate regions.

The growth rings in the pieces of coniferous charcoal are clearly defined. In their general nature and breadth, they are similar to those that occur in most coniferous trees growing today in temperate climates. A transverse section of a piece of charcoal from Skansen, 2 miles inland at an altitude of 140 meters is shown on Plate 20, Figure 67. The growth ring in this specimen is distinct, with a known breadth of about 3.2 mm. A cross section of another

specimen (Plate 20, Figure 70) from Skansen, 2 miles inland at an elevation of 385 meters, shows three lines of growth in a width of about 2 mm. but as this specimen is badly crushed its actual breadth would be slightly more than that given. Other specimens from the same locality, but not figured, show from one to three growth rings similar to those mentioned.

Discussion and Conclusion

The study of the coals of Western Greenland adds a new aspect to the fossil floras from that region. This new coal flora is based on the remains of plants that no doubt inhabited bogs or swamps. At present it is impossible to correlate the coal beds of Western Greenland with those of other regions because of the lack of information concerning the plant remains of other coals.

Not all of the coal studied can be correlated with each other as some of the coal samples did not yield sufficient or satisfactory plant remains. Definite correlations can be established between some of the coal deposits at Skansen and at Patoot.

Spermatites elongatus, S. ellipticus, and *S. nanus* occurred at Skansen, 2 miles inland at elevations of 140 and 385 meters. *S. ellipticus* also occurred at Patoot at an altitude of 165 meters, and *S. orbicularis* was found at the above locality as well as at Skansen, 2 miles inland at the altitude of 140 meters. *Selaginellites Arnoldii* and *S. borealis* both occurred at Skansen, 2 miles inland at an elevation of 140 meters and at Patoot at an altitude of 165 meters, but in addition *S. Arnoldii* was found at Patoot at a height of 85 meters. The distribution of the above mentioned species probably shows that the coal beds in which they occurred are closely correlated. It correlates beds at Skansen, Disko Island, 2 miles inland at heights of 140 and 385 meters, with those at Patoot, Nugsuaks Peninsula, at altitudes of 85 and 165 meters.

The distribution of this coal flora is summarized in Table I. The occurrence at different horizons of some of the same types of plant fragments, such as cuticles and carbonized wood, indicates also that these beds must have been formed by the same species or closely related ones.

The modern groups presumably represented by this flora are the Bryophyta, Pteridophyta and Spermatophyta. The Bryophyta are doubtfully represented by one species of *Chrysotheca;* the Pteridophyta by nine species of *Selaginellites,* and two species of *Thecopteris;* the Spermatophyta by representatives of the Gymnospermae and Angiospermae. The former are represented by three types of cuticles which may belong to the Coniferae, and by *Cedroxylon* spp. as indicated by the various fragments of carbonized wood. The Angiospermae present belong to the Dicotyledoneae, as is shown by the three species of *Phyllodermium.* The other types of cuticles apparently belong to the angiosperms. There are ten species of plants of uncertain affinities classified as follows: seven species of *Spermatites*, two species of *Carpolithus,* and one species of *Alatampulla.* A fossil of altogether uncertain position, *Arcellites,* is also present. It is probably an animal.

The present paper opens up a new field in the paleobotanical study of Mesozoic and Tertiary coals. Needless to say, much more must be done be-

fore extensive correlations of coals on the basis of botanical composition become possible. The characteristic and readily diagnosed fossils, however, give every reason to believe that the investigations will become cumulatively important as they are carried farther. It is the writer's intention to continue his studies which were begun here.

Summary

1. The fossils described in this study are all new, and they add a new phase to the paleobotanical and geological history of the fossil floras from Western Greenland.

2. Nine different genera are discussed, six of which are new; twenty-six species are discussed.

3. Eight types of cuticles or similar tissues that represent the most abundant ones recovered from this coal are discussed. Three of these types apparently belong to the gymnosperms, and the other five types belong to the angiosperms.

4. All the carbonized wood is coniferous. The tracheid pitting is abietineous in character.

5. Correlations are established between some of the coal beds at Patoot and Skansen.

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PLATE 18

(The numbers given are the catalogue numbers of the Museum of Paleontology, University of Michigan).

FIGURES

1–10. *Chrysotheca diskoensis*. x30. Cotypes. Slides No. 15455, 15456.

11–15. *Thecopteris major*. Figures 11 and 12 show the sporangia with the annuli partly surrounding the central mass of spores. x55. Figure 13, a circular mass of spores. x55. Figures 14 and 15, the characteristic spores. x340. Cotypes. Slides No. 15460-15463.

16–19. *Thecopteris minor*. Figure 16 shows the general shape of the sporangium. x55. Figure 17, a mass of spores. x55. Figures 18 and 19, the characteristic spores. x340. Cotypes. Slides No. 15460, 15462, 15464.

20. *Alatampulla Bartlettii*. x15. Cotype. Slide No. 15457.

21. *Carpolithus amisutensis*. x11.6. Holotype. Slide No. 15458.

22. *Selaginellites Arnoldii*. x90. No. 15466.

23–25. *Carpolithus patootensis*. Three different views of the same specimen. x5. Holotype. No. 15459.

26-28. *Spermatites orbicularis*. x30. Cotypes. Slides No. 15477, 15480.

PLATE 18

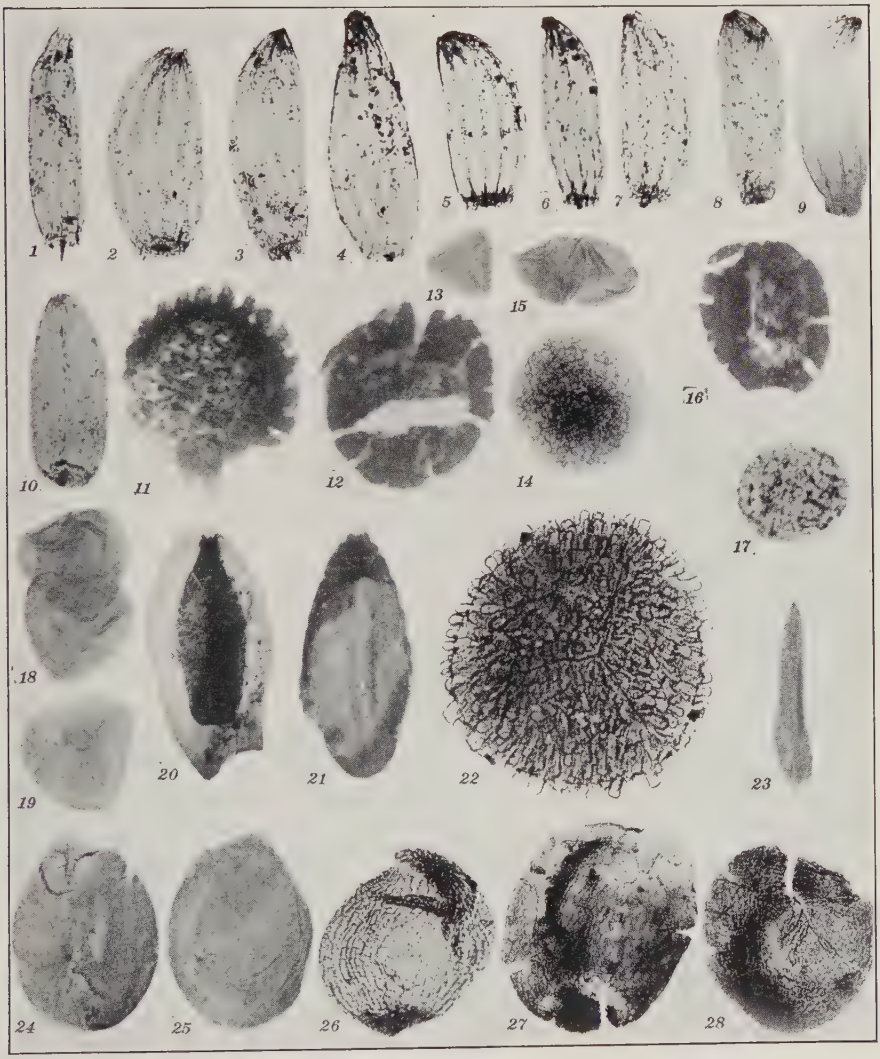

PLATE 19

FIGURES

29–38. *Spermatites elongatus*. x30. Cotypes. Slides No. 15468, 15469, 15471, 15474, 15475, 15479-15481.

39–40. *Spermatites ovatus*. x30. Cotypes. Slides No. 15472, 15480.

41–47. *Spermatites ellipticus*. x30. Cotypes. Slides No. 15470, 15473, 15476-15478, 15480.

48–51. *Spermatites arcuatus*. x30. Cotypes. Slides No. 15468, 15472, 15478.

52-54. *Spermatites nanus*. x30. Cotypes. Slides No. 15479, 15481.

55. *Spermatites pylophorus*. x30. Cotype. Slide No. 15480.

PLATE 19

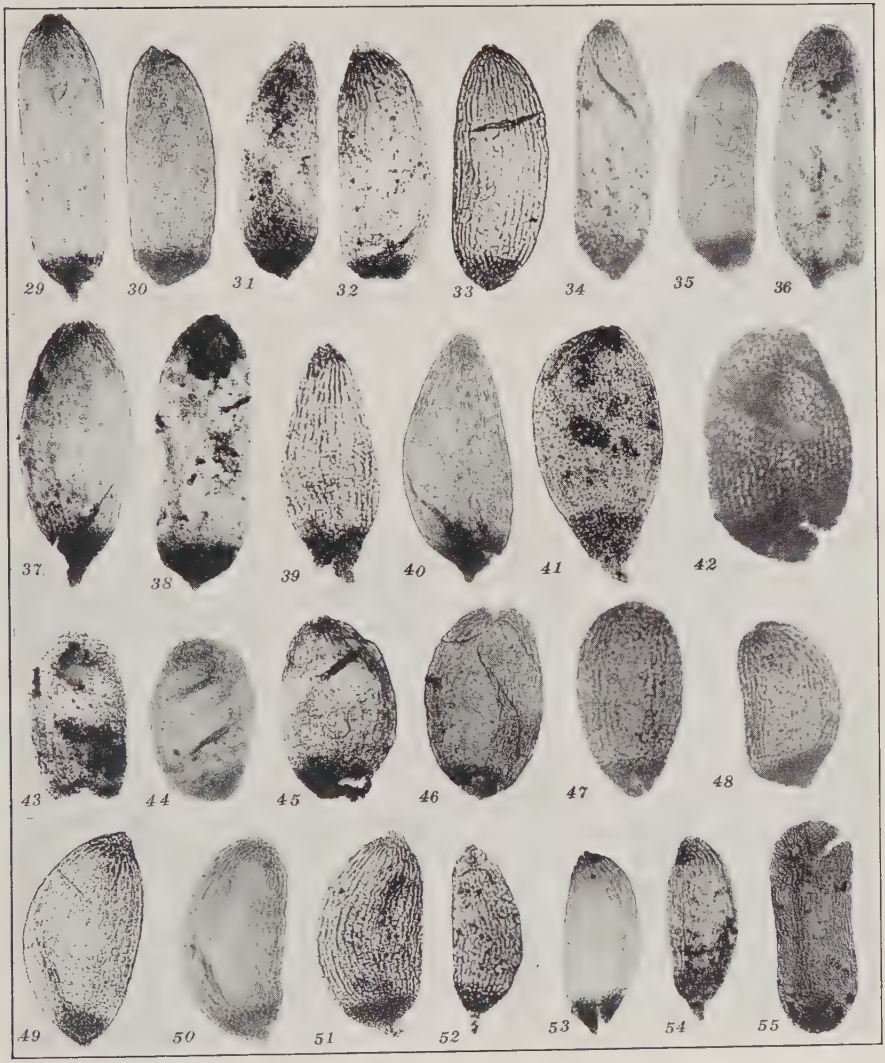
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PLATE 20

FIGURES

56–60. *Spermatites pylophorus.* x30. Cotypes. Slides No. 15467, 15475, 15478, 15480.

61. *Arcellites disciformis.* x100. Cotype. Slide No. 15497.

62. *Phyllodermium perplexum.* x95. Cotype. Slide No. 15483.

63. Cuticle Type A. x95. Slide No. 15487.

64–66. *Arcellites disciformis.* x100. Cotypes. Slides No. 15497, 15498.

67–69. Transverse and radial sections from a piece of charcoal. Figure 67 shows one growth ring. x15. Figure 68, an enlargement of a portion of the growth ring shown in Figure 67. x130. Figure 69, a radial section showing a part of a ray and the bordered pits on the tracheids. x130. Slide No. 15502.

70–71. Transverse section of a piece of charcoal showing three distinct growth rings. x15. Figure 71, an enlarged portion of Figure 70. x130. Slide No. 15503.

PLATE 20

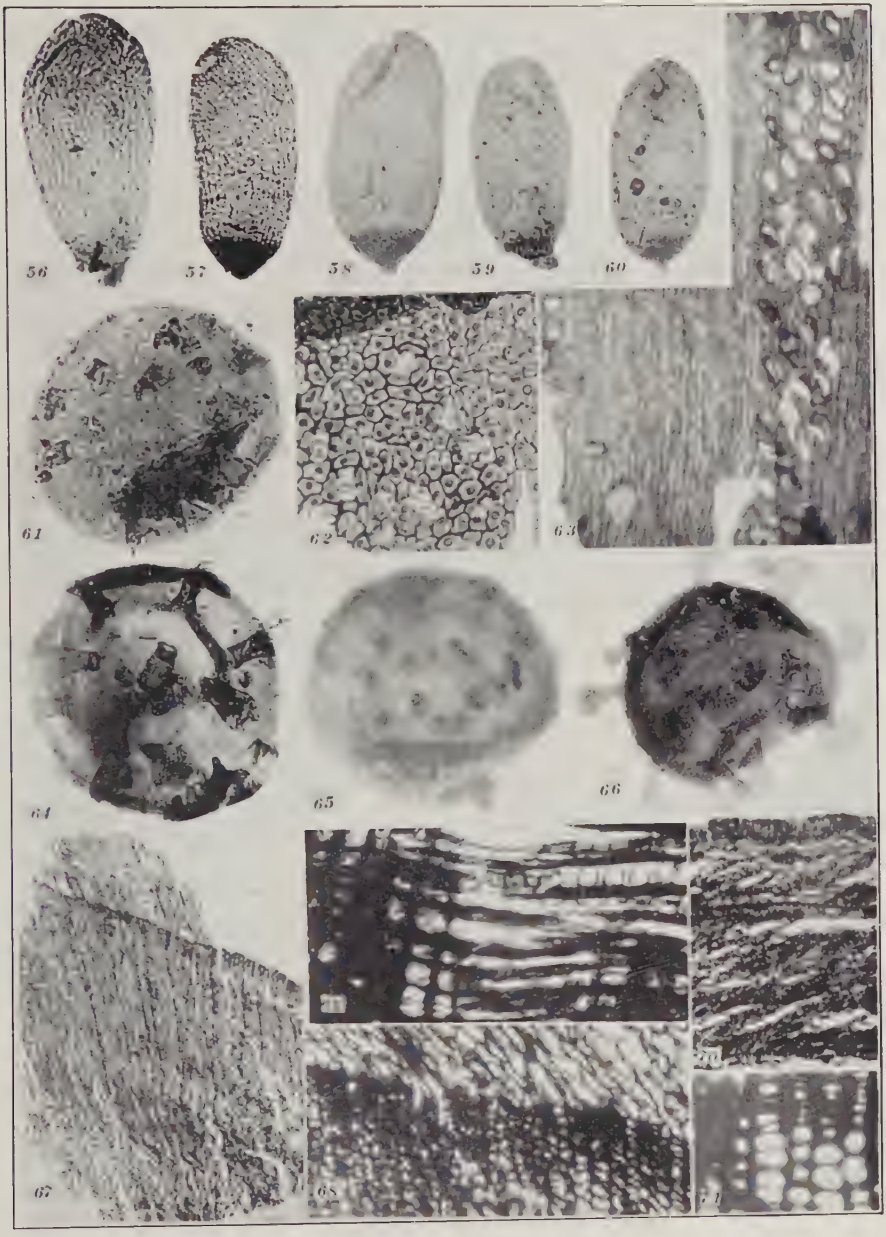


PLATE 21

FIGURES

72–73. *Phyllodermium Reinschii.* Figure 72, general arrangement of stomata. x95. Figure 73, an enlargement of a portion of Figure 72. x340. Cotype. Slide No. 15486.

74–75. *Phyllodermium nervosum.* Figure 74, the general arrangement of the stomata. x95. Figure 75, an enlargement of a portion of Figure 74. x340. Holotype. Slide No. 15482.

76–77. *Phyllodermium perplexum.* Figure 76 shows the distribution of the stomata. x95. Figure 77, an enlargement of a portion of Figure 76. x340. Cotype. Slide No. 15483.

PLATE 21

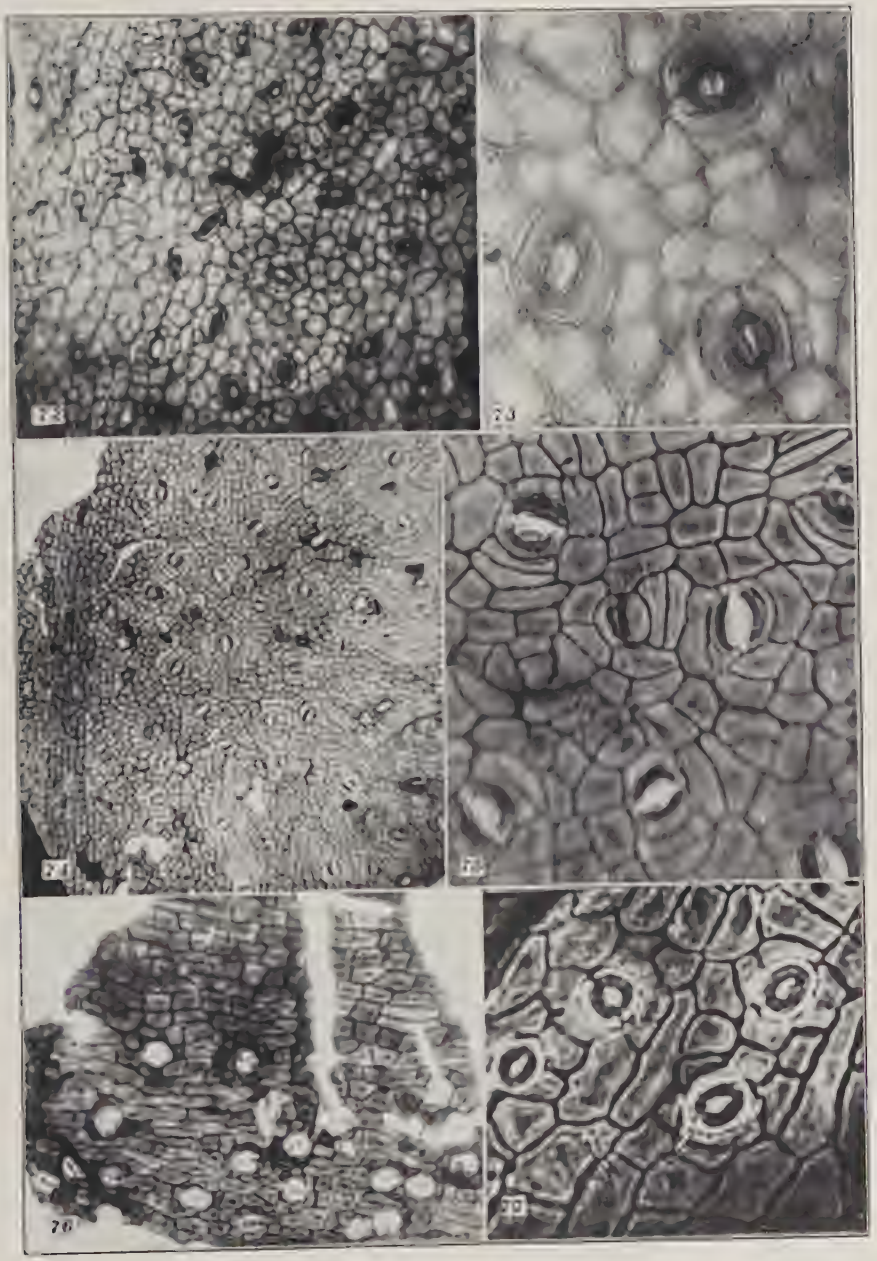


PLATE 22

FIGURES

78. Cuticle Type B. x95. Slide No. 15483.

79. Cuticle Type C. x95. Slide No. 15483.

80. Cuticle Type D. x95. Slide No. 15492.

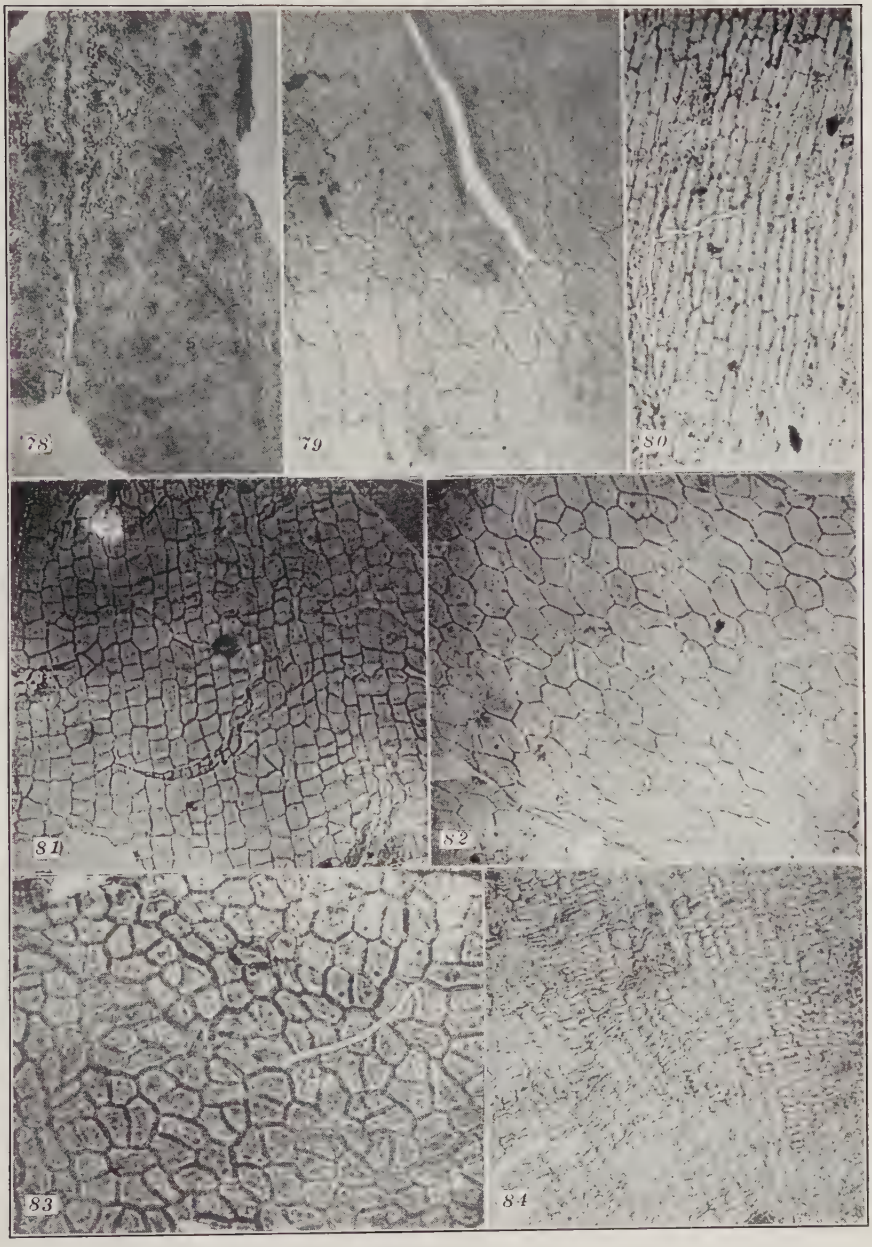
81. Cuticle Type E. x95. Slide No. 15489.

82. Cuticle Type F. x95. Slide No. 15488.

83. Cuticle Type G. x95. Slide No. 15491.

84. Cuticle or cellular tissue Type H. x95. Slide No. 15490.

PLATE 22



II. CRETACEOUS AND TERTIARY COALS FROM MONTANA*

The plant fossils studied in this report were recovered from coal which came from Cascade and Carbon counties, Montana. The Cascade County sample was collected by Dr. Louis Hall of Ann Arbor, and given by him to Professor H. H. Bartlett who turned the material over to the writer. The Carbon County sample was secured from Mr. W. H. Homer, operator of the Homer Coal Mining Company at Bear Creek, Montana. Coal vein No. 4.

The coal deposits of Cascade County are in the Great Falls coal field (Barrett, 1916; Fisher, 1907) and throughout this field the coal occurs in the lower part of the Kootenai formation, which is of Lower Cretaceous age (Fisher, 1909).

In Carbon County the coal beds belong to the Bear Creek coal field (Fisher, 1906) or to the Red Lodge coal field (Woodruff, 1909). The same coal seams occur in both the Bear Creek and Red Lodge districts. The exact formation in which the coal beds of this field belong appears to have been rather difficult to determine. Fisher (1906) stated that the coal of Bear Creek district occurs in the upper part of the so-called Laramie formation, but the later works of Darton (1907), Woodruff (1909), and Calvert (1916) all agree in placing it in the Fort Union formation, which they considered as belonging to the lower portion of the Tertitary. Darton (1907) in commenting upon the Cretaceous system in this basin states that the upper limits could not be ascertained and that probably a large part of the upper beds, as well as the Red Lodge-Bear Creek coal bearing rocks are of early Eocene or Fort Union age.

For many years there has been considerable controversy over the stratigraphic position of the Fort Union formation. The data available concerning the position or age of this formation has been interpreted in various ways by different paleontologists; some have placed it at the top of the Cretaceous, but others have put it at the base of the Tertiary.

In many localities the Fort Union formation lies immediately above the Cannonball member of the Lance formation, and Stanton (1920) after making a study of the fauna of the Cannonball member concluded that it and consequently the whole of the Lance formation is of Cretaceous age. All of the evidence does not allow for the existence of a long unrepresented interval any-where between the Fox Hills and Wasatch formations. From the faunal evidence as given by Stanton, Schuchert (1921, 1922) concluded that the division between the Mesozoic and Cenozoic apparently lies between the Fort Union and Wasatch formations and not the Fox Hills and Lance beds.

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* Papers from the Department of Botany and Herbarium of the University of Michigan, No. 460.

Miller (1928) also places the Fort Union at the top of the Upper Cretaceous as Schuchert (1924) still maintains that it should be.

The works and opinions of such investigators as Cross (1921, 1922), Knowlton (1921, 1922), Simpson (1929), Scott (1932), Jepsen (1930), Russell (1930), Schuchert and Dunbar (1933), and others, indicate that Fort Union belongs to the Tertiary. Knowlton (1921, 1922) states that the Fort Union flora is typically Eocene in age and that there is a floral continuity between the Lance and the overlying beds of the Fort Union. Therefore the two formations should not be separated but considered as being of the same age. The paleozoological evidence does not support the paleobotanical view given by Knowlton. Simpson (1929) from his study of the Fort Union mammalian fauna at Bear Creek, Montana, places the Lance formation at the summit of the Upper Cretaceous and the Fort Union in the Paleocene, which is the oldest of the Tertiary series. Scott (1932) likewise considers the Fort Union as being in the Paleocene. In their latest work Schuchert and Dunbar (1933) state that the faunal evidence now appears to be conclusive that the Fort Union formation belongs to the Cenozoic. Beds identified as Fort Union show a definite correlation with the oldest Cenozoic or Paleocene formations. The Lance formation with its dinosaurs is clearly the latest interval of the Cretaceous.

This report presents a few characteristic plant fossils recovered from coal belonging to the Kootenai and Fort Union formations. It is hoped that as more work of this nature is done, these fossils will prove to be of more stratigraphic importance.

During the course of this study about 45 samples of coal were examined. The samples were secured from the coal fields of Montana, Wyoming, Colorado, Utah, and New Mexico; but, as yet, no recognizable fossils have been found in the other samples.

The cotypes are in the collections of Ernest L. Miner and the Museum of Paleontology, University of Michigan. The numbers given are the catalogue numbers of the Museum.

The coal was macerated in bulk and the larger isolated plant fragments, with the exception of the charcoal were mounted on slides in euparal (Miner, 1932).

"Smear" mounts (Miner, 1935) were made of the finer plant remains that were too small to be recovered with a binocular microscope.

The charcoal was embedded in paraffin by the butyl alcohol method, and then cut into serial sections on a rotary microtome. The sections were mounted on slides without removing the paraffin because if the paraffin were removed the charcoal would crumble to pieces. Euparal was used as the mounting medium.

The plant remains from the Cascade coal consisted mostly of cuticles and a few spores. The Carbon County sample contained some very interesting and characteristic megaspores, a few pieces of fairly well preserved charcoal,

and some cuticles. The plant remains in the Cascade coal appeared to have undergone more distintegration than those in the other sample.

Selaginellites mirabilis sp. nov.

Plate 23, Figs. 1-6.

Body of exine round, 332-498μ in diameter, the average being 395μ; exine covered with irregular reticulate ridges which extend up part way on the wings; triradiate markings extend beyond the periphery; diameter on the radii of the triradiate markings 430-630μ; triradiate markings winged, wings 67-150μ in width, the average width being about 90μ; equatorial ring present. Bear Creek, Carbon County, Montana; Fort Union formation. Cotypes. Slides No. 15510, 15511, 15512, Museum of Paleontology, University of Michigan. This beautiful megaspore is quite abundant and appears to be characteristic of the coal. The shape and appearance of this spore varies somewhat, depending upon the plane in which it was flattened. When compressed so that it can be viewed from the inner or outer faces it is triangular in shape (Figures 1-3), but when flattened laterally the rounded outer face can be seen with the wing of the triradiate markings extending up over the inner face and the equatorial ring separating the two faces (Figures 4-6).

The presence of the equatorial ring is quite interesting as it is present on megaspores of *Isoetes*, but it is not always present or evident on megaspores of *Selaginella*. For a more complete discussion of megaspores of this type the reader is referred to a previous article (Miner, 1932).

Deltoidospora gen. nov.

Small unassigned deltoid or sub-deltoid spores of the type that is commonly found associated with many Mesozoic ferns; such as *Gleichenites, Gleicheniopsis, Laccopteris,* and others.

Deltoidospora Hallii sp. nov.

Plate 24, Figs. 7-8.

Body of exine deltoid, 33-39μ in diameter; sides straight or slightly curved inwards; triradiate clefts extend two thirds or more of the distance to the periphery. Cascade County, Montana; Kootenai formation. Cotypes. Slides No. 15515, 15516, Museum of Paleontology, University of Michigan.

Deltoidospora cascadensis sp. nov.

Plate 24, Figs. 9-12

Body of exine sub-deltoid, 30-41μ in diameter; sides rounded; triradiate clefts extending two thirds or more of the distance to the periphery. Cascade County, Montana; Kootenai formation. Cotypes. Slides No. 15515, 15516, Museum of Paleontology, University of Michigan. This species somewhat resembles *Sporonites Neddeni* of Potonié (1931), from the Tertiary brown coal of Germany, but the great difference in the age makes it hardly seem possible to consider them as belonging to the same species. In the form-genus *Sporonites,* Potonié places a great variety of small unassigned spores.

The generic designation *Deltoidospora* as used here includes the isolated spore types that are common to many Mesozoic ferns.

Sporonites montanensis sp. nov.
Plate 24, Figs. 13-16.

Body of exine round or nearly so, 55-60μ in diameter; no triradiate clefts or other markings visible. Cascade County, Montana; Kootenai formation. Cotypes. Slides No. 15515, 15516, Museum of Paleontology, University of Michigan.

Cedroxylon sp.
Plate 24, Figs. 17-20.

In the sample of coal from Bear Creek, a piece of charcoal was discovered which in transverse section shows ten distinct growth rings. The charcoal was so badly crushed that not much detail, other than the arrangement of the bordered pits on the radial walls of the tracheids, could be observed.

The bordered pits are circular, and are arranged in one, two, or three vertical rows on the tracheids. The rows are opposite and the bordered pits are usually separate. A single tracheid sometimes has a combination of all three arrangements. Slide No. 15514, Museum of Paleontology, University of Michigan.

The medullary rays are narrow and have few to several pits per tracheid. The exact height and width of the rays could not be determined.

Distinct bars of Sanio are present on some of the tracheids but apparently absent from others.

The arrangement of the bordered pits on the radial walls of the tracheids and the pitting on the ray cells is very similar to that found in *Cedroxylon Nordenskjoldi* described by Mathiesen (1932) from some fossil wood collected at Turner Sound, East Greenland.

Among the genera for fossil coniferous woods this material can be placed in the form-genus *Cedroxylon* as defined by Bailey (1933).

The presence of the growth rings in this carbonized wood indicates that the climate, at the time the coal was deposited, was temperate. In order for such extensive coal deposits to accumulate during early Tertiary time, there must have been extensive aquatic and subaquatic habitats.

The plant remains recovered from these Montana coals are of similar types, i.e., spores, charcoal, cuticles, to those found in the coals from Western Greenland (Miner 1932, 1935), but the species represented are entirely different. *Selaginellites mirabilis,* which is the characteristic spore type found in the Bear Creek sample, is quite different from any of the species of the genus that were found in the coal from Skansen, Disko Island, and Patoot, Nugsuaks Peninsula, Western Greenland.

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PLATE 23

FIGURES

1–3. *Selaginellites mirabilis*. Spores compressed horizontally, so that they are triangular in shape.

4–6. *Selaginellites mirabilis*. Spores compressed laterally. x103. Cotypes. Slides No. 15510, 15511, 15512, Museum of Paleontology, University of Michigan.

PLATE 23

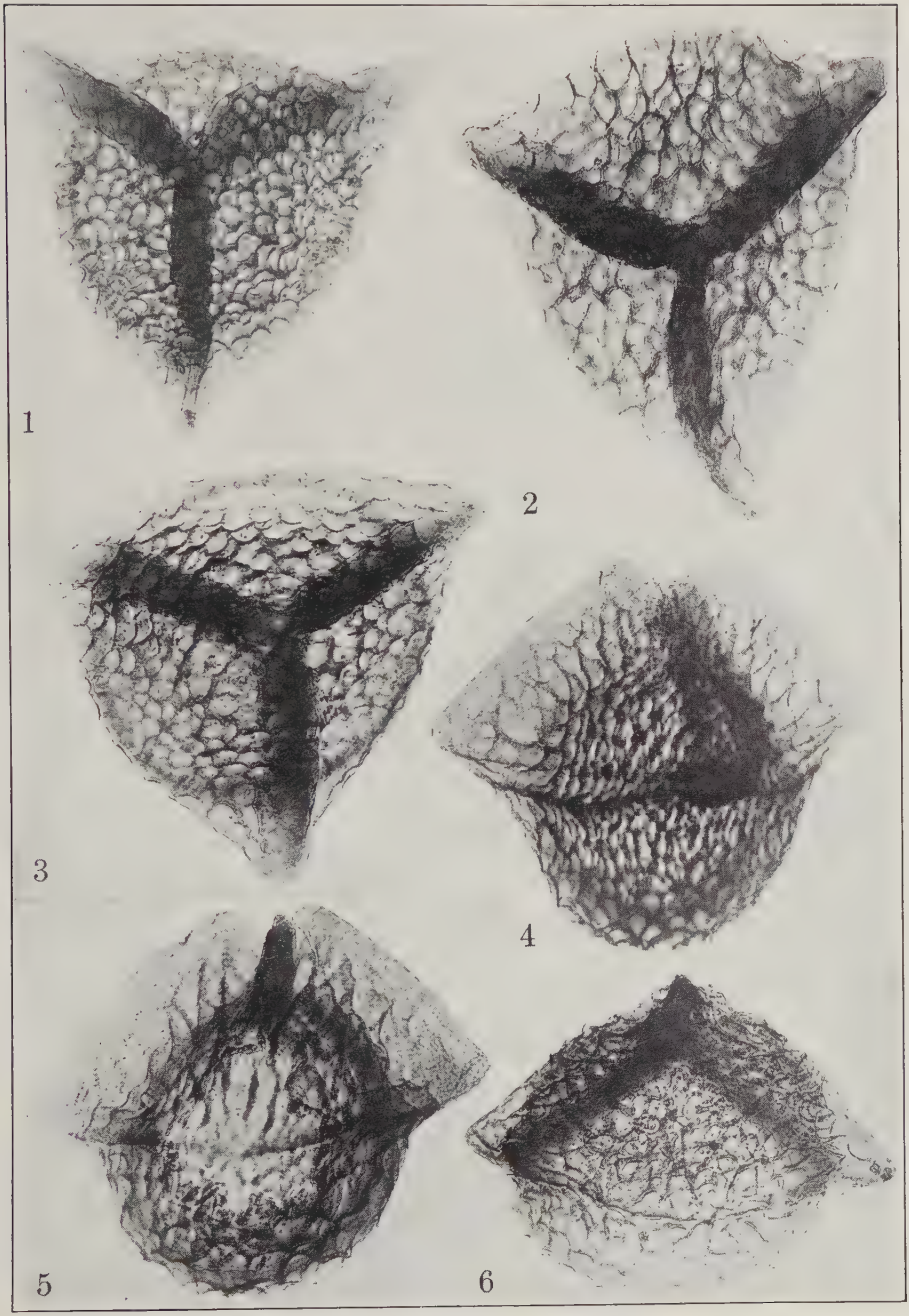

PLATE 24

FIGURES

7–8. *Deltoidospora Hallii.* x340. Cotypes. Slides No. 15515, 15516, Museum of Paleontology, University of Michigan.

9–12. *Deltoidospora cascadensis.* x340. Cotypes. Slides No. 15515, 15516, Museum of Paleontology, University of Michigan.

17–20. Tracheids from the charcoal, showing the arrangement of the bordered pits. Bars of Sanio can be seen in figures 18-20. x440. Slide No. 15514, Museum of Paleontology, University of Michigan.

PLATE 24